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ABSTRACT

Research studies which compare individualized elementary school mathematics instruction to other instructional approaches are summarized in this paper. First, brief descriptions are given of Individually Prescribed Instruction, Program for Learning in Accordance with Needs, and other self-paced approaches. Next, a general overview of the research studies is presented, covering research design, length of time of the studies, characteristics of the participating students, and criterion measures used. Finally, the results of the studies are reported for kindergarten to fourth grade, fifth to eighth grade, and educable mentally retarded students. (DT)

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INDIVIDUALIZED MATHEMATICS INSTRUCTION: HOW EFFECTIVE HAS IT BEEN IN THE ELEMENTARY SCHOOL?

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by

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The January, 1972, issue of The Arithmetic Teacher was dedicated to individualizing mathematics instruction in the elementary schools. Most of the articles in that issue dealt with self paced modularized approaches to individualization. Since then a substantial amount of research investigating the effectiveness of this approach has been reported. This paper is a summary of research studies comparing elementary school mathematics instruction via this individualized approach to other instructional approaches. The results may be surprising to some but any elementary educator involved in mathematics instruction will find them very interesting and useful.

Many of the research studies cited include Individually Prescribed Instruction (IPI) or Program for Learning in Accordance with Needs (PLAN) as one of the treatments. Following is a brief description of each.

IPI

In 1964 work was begun at The Learning Research and Development Center in Pittsburgh to develop an individualized instruction system. Some major characteristics of IPI are the following.

1. Specific behavioral objectives are listed.
2. A variety of instructional activities are included at eight levels of difficulty.
3. Diagnostic tests for placement, pretests of units and post-tests of units are all included. Some curriculum embedded tests also serve to assess mastery.
4. Tests are scored by the student or by teacher aides.
5. The teacher diagnoses the students needs and prescribes the next assignment based on this diagnosis.

6. The IPI arithmetic program is primarily computational with little emphasis on concept development.

The overall aim of IPI is to provide a model curriculum for elementary schools that is both cost effective and capable of providing all kinds of children with an individualized education (Edmunds, 1971; p. 13).

Since 1966, Research for Better Schools has directed large scale testing of the IPI system. Positive results are reported (Edmunds, 1971) though many studies cited in this review are not in agreement with that conclusion.

PLAN

In 1967 the Westinghouse Learning Corporation began development of PLAN. Flanagan (1970) lists some of the characteristics of PLAN.

1. Each module contains five objectives and includes approximately a two-week segment of instruction.
2. Each module contains a teaching-learning unit, a four-page guide listing the objective, and the materials the student should use.
3. Effort is made to provide for individual differences with alternative instructional methods.
4. Mastery tests and affective measures of several types are included.
5. The teacher provides guidance for individual students in planning their program.
6. Westinghouse provides computer test scoring and record keeping to PLAN users.

PLAN has also been evaluated extensively for purposes of revision and

to assess effectiveness. PLAN is designed to be adaptable to an existing curriculum while IPI is essentially self-contained, though their approaches to individualization are very similar.

Other Teaching Approaches

A substantial number of the studies cited included a teacher or researcher designed individualized program. Unless otherwise stated these programs involved student self pacing within a sequence of learning packets or units. It was the individual student's responsibility to achieve the objectives specified in each learning packet. Many of the approaches involved a variety of media but for the most part students learned independently from textbooks or worksheets at their own pace. Pretests and posttests were included with each learning packet and passing one or both of these was a prerequisite to progress to the next packet. The teacher's role was that of manager, record keeper, individual tutor, and sometimes curriculum developer.

Certainly the self paced programs were not identical but they had those characteristices cited above in common with each other and with IPI and PLAN. The few exceptions to this will be noted.

In many studies, the individualized treatment is compared to a "traditional" treatment. The researchers did not always describe this method in great detail. With some noted exceptions, the traditional method was teacher centered and teacher paced with common tests given at the same time to all twenty to thirty-five students within a self contained classroom. Again, the traditional approach differs from one study to another but these are common characteristics which mark the contrast to the individualized approach.

General Description of the Studies

Due to space limitations the discussion of individual studies must be very

brief. There are some characteristics common to nearly all the studies. Only exceptions to these will be noted in the discussion of the individual studies. First, only studies in which the comparison groups were "equivalent" before the study are reported. The methods of achieving equivalence were random assignment of students or classes to treatments, matching one treatment group to another on several variables such as sex, IQ or previous mathematics achievement, or statistical equating by analysis of covariance or the use of pretest to posttest change scores as criterion measures.

Second, the length of the studies were typically one academic year. Third, the students comprising the samples were white, middle class, normally distributed students on school variables as well as socio-economic variables. Several exceptions to this are noted and are worth separate consideration. The sample sizes, excepting the educable mentally retarded studies, ranged from sixty two to over one thousand,with a median of about three hundred fifty.

Fourth, the criterion measures (dependent variables) were typically standardized arithmetic achievement tests and their subtests and some commonly used attitude scales. The specific test used in each study will not be reported here. The Iowa Test of Basic Skills, Stanford Achievement Tests-Arithmetic, SRA Mathematics Battery, Sequential Test of Educational Progress-Mathematics, and Comprehensive Test of Basic Skills are some of the achievement tests utilized. The attitude scales were, for example, Semantic Differential Attitude Toward School, Aiken's Revised Mathematics Attitude Inventory, and Scriven Attitude Sirvey. Analysis of variance and t-tests were the most common statistical techniques used to test differences in group means. Unless otherwise stated statistically significant means differences at the .05 probability level. Readers interested in

more details about specific studies must, unfortunately, refer to the source as listed in the References.

Finally, there seemed to be distinct differences in the findings for younger students as compared to older elementary students, and for educable mentally retarded students as compared to "normal" students. Thus, the results for these groups are discussed separately, followed by some interpretations of the findings for all groups.

Kindergarten to Grade Four

Evidence concerning the effectiveness of IPI at this level is mixed. Harper (1973) found that fourth and fifth graders taught in an IPI system scored significantly higher in achievement than both a traditionally taught group and a group taught by a small group approach. Clough (1971) found that IPI first graders, but not second and third graders, scored significantly higher in mathematics computation than traditionally taught first graders. No significant differences were found at the other grade levels or in concept, reasoning, or total mathematics achievement at any of the three grade levels.

No significant differences in arithmetic achievement were found between IPI students and traditionally taught students in grades three, four and five (Fisher, 1968), in grades three and four (Johnson, 1972), in grades one to six (Meade and Griffin, 1969), and in grades one to three (Gaskill, 1971). Fisher's (1968) study also included programmed instruction as a treatment with no significant differences in mathematics achievement among the three treatments.

Taylor and Fleming (1972) had found arithmetic achievement differences favoring IPI over a traditional approach after one year of IPI. However, in this, their third year evaluation, they found significant differences in computational skills in grades two, three and four, and significant differences in

both computation and concepts in grades four, five and six all favoring the traditional group.

Only one study with students at this level involving PLAN was found. Abate (1973) used a sample of students from grades one through four and analyzed the results grade level by grade level. The fourth grade traditional group's mathematics achievement mean was significantly higher than the PLAN fourth graders but no significant differences in achievement were found at the other grade levels. Abate also found the PLAN first graders had a significantly more positive attitude toward school than the traditional first graders while at the fourth grade level the reverse was true. No significant differences in attitude toward school were found in grades two and three.

Teacher and researcher developed individualized programs fared about as well as IPI and PLAN when compared to other methods. Two researchers report mathematics achievement gains in an individualized program to be significantly greater than those in comparable traditionally taught classes (Broussard, 1971; Bradford, 1973). Broussard's findings involved inner city fourth graders and occurred in the arithmetic skills and concepts subtests as well as in overall mathematics achievement.

No significant difference in mathematics achievement between an individualized group and a comparison group was found at the kindergarten and first grade level (Godde, 1973), the fourth grade level (Bartel, 1966; Gibish, 1971; Putbrese, 1972), and in grades one through six (Tychsen, 1971). Bartel (1966) did find the individualized group mean on the concepts subtest to be significantly higher than that of the traditional group. Other criteria were analyzed in some of the above studies and the findings are summarized in Table 2.

In a comparison study involving third, fourth and fifth graders, Burchyett

(1973) found the fourth grade traditional group's mathematics achievement mean to be higher than the individualized group's mean, but no significant differences were found in grades three and five. In another study, traditionally taught second graders scored significantly higher in arithmetic achievement than a comparable individualized group (Earnshaw, 1973). However, Earnshaw's individualized treatment appears to be considerably less structured than IPI.

Wasden (1971) compared students in individualized elementary schools and comparable traditional schools in five school districts. Arithmetic achievement was one of several criteria used. Consistently, with few exceptions the traditional students significantly outscored the individualized students in arithmetic skills. The individualized students performed better only in a test of language arts among the seven achievement criteria.

Table 1 summarizes the arithmetic achievement findings. The mixed

Table 1

Summary of Arithmetic Achievement* Results in Kindergarten to Grade Four

Individualized Approach	Favored Individualized	Favored Control	N. S. D.
IPI and PLAN	Clough, 1971	Taylor, 1972	Johnson, 1972
	Harper, 1973	Abate, 1973	Meade and Griffin, 1972
			Gaskill, 1971
			Fisher, 1968
Researcher or Teacher Developed	Broussard, 1971	Burchyett, 1973	Godde, 1973
	Bradford, 1972	Earnshaw, 1973	Tychsen, 1971
	Bartel, 1966	Wasden, 1971	Putbrese, 1972 Gibish, 1971

*Some researchers analyzed achievement gain scores, some posttest achievement scores and others adjusted posttest means using covariates. In addition, studies are listed as favoring an approach if significant differences were found on any achievement subtest.

results are further discussed in a later section. Individualized instruction fared better on other measured variables, particularly affective variables. Most researchers reported "positive attitudes" of teachers and students toward the individualized approach. However, only those studies which included an objective measure of the respective variable are given consideration here. In only one such case did scores on an affective measure favor the traditional approach, though several researchers reported no significant differences. The findings are summarized in Table 2.

Table 2

Summary of Other Criteria in Kindergarten to Grade Four

Criterion	Favored Individualized	Favored Control	NSD
Attitude toward School	Abate, 1973 (Grade 1 only) Godde, 1973 Earnshaw, 1973	Abate, 1973 (Grade 4 only)	Gibbish, 1971 Tychsen, 1971
Motivation	Earnshaw, 1973		
Self Concept	Bradford, 1973 Gaskill, 1971 (low ability only)		
Time Series Achievement			Puthrese, 1972
Retention			Puthrese, 1972

Fifth Grade to Eighth Grade

Studies involving eighth and ninth grade general mathematics students are included in this section. Algebra one studies, regardless of grade level, are excluded.

In only one of seven studies which included IPI or PLAN as a treatment were

significant differences in mathematics achievement in favor of, in this case, IPI reported. In an ESEA Title III final program evaluation, thirty IPI sixth graders scored significantly higher in mathematics achievement than thirty randomly selected sixth graders in the same school district (Project Skill, 1972). No significant differences in measures of attitude toward school or of attitude toward mathematics were found. Shumaker (1972) found no significant differences (IPI versus traditional) in mathematics achievement, study habits or attitudes toward mathematics at the end of the seventh grade.

In the remaining three studies which involved IPI, results in mathematics achievement favored the control group. Verheul's (1972) traditional sixth graders outscored the IPI group in both arithmetic computation and total mathematics achievement, while analysis of several other criteria yielded mixed results. Thomas (1972) reported mathematics achievement differences in favor of the traditional group of fifth and sixth graders, too, but attitude toward school changed more positively in the IPI group.

One of the studies most damaging to IPI is that of Fiedler (1972). Using students who were in the fifth and sixth grades at the end of a two year study, he found much greater achievement gains in the traditional group than in the IPI group on all subtests and the total score on the Stanford Achievement Test-Arithmetic with no reversals at either grade level ($p < .001$ in the sixth grade and $p < .002$ in the fifth grade).

Two researchers using fifth grade subjects found results favoring a traditional group over a PLAN group. Ferney's (1970) criterion was arithmetic reasoning. Brust (1972) found highly significant differences ($p < .001$) in arithmetic computation in favor of the traditional group, but no significant differences on the subtests of the Stanford Achievement Test.

Of the eleven studies located in this category in which the individualized approach

was teacher developed, findings favoring the individualized group in mathematics achievement were reported in only two. Malcolm (1973) found a significant difference in total mathematics achievement in favor of individualized seventh graders and in arithmetic skills in favor of individualized seventh, eighth, and ninth graders. Attitude toward mathematics was also significantly better in the individualized seventh and ninth grades, but not eighth grade, compared to their traditionally taught counterparts. In another study, eighth grade boys of average mathematics ability and below average IQ scored significantly higher in mathematics achievement in an individualized program than in a traditional one (Nix, 1970). No significant differences were found in other categories or in the total group, however.

In one of the few studies which was conducted in Europe, Larsson (1973) reported on Sweden's Individualized Mathematics Teaching Project (IMU). IMU is aimed for grades seven, eight, and nine. It is a modularized program with just nine modules for the three grades, thus not fitting the IPI or PLAN paradigm. However, it was, at least initially, a student paced program. Larsson reports that control of progress was returned to the teacher after some initial bad experiences. When students in IMU were compared to a control group, no significant attitude differences were found and since the IMU students were volunteers and initially superior to the control students, Larsson reports that no achievement comparisons were meaningful.

One other researcher reported no significant difference in mathematics achievement gains between an individualized group of eighth graders and a control group (LaPlaca, 1974).

Seven researchers reported mathematics achievement differences favoring a control teaching approach over a researcher or teacher prepared individualized

approach. Whipple (1972) conducted a fourteen day study. He compared two groups of eighth graders--one taught a unit of metric geometry by a laboratory method and the other by individualized learning packets. The mean scores of the laboratory group on each of two researcher constructed achievement tests were significantly higher than the means of the individualized packet group.

Three year-long studies with junior high samples also resulted in higher mathematics achievement by the traditional group (Crangle, 1971; Schaefer, 1972; Wheaton, 1972). Schaefer (1972) found achievement differences at the .01 probability level and no significant difference on a measure of self esteem. Crangle (1971) reported that the higher achieving traditional group also took significantly less time to reach their achievement level than did the individualized group.

O'Neill (1971) reported similar findings with disadvantaged, inner city fifth graders. The traditional group scored significantly higher than the individualized group on a researcher developed mathematics achievement test, while no significant difference in attitude toward mathematics was found.

In a semester-long study involving five hundred sixty students from grades one to eight, Amendola (1973) used cognitive and affective measures to compare students in a continuous progress program to a traditionally taught control group. Comparisons of cognitive measures were only made with third, fifth and seventh graders. The attitude and achievement measures were administered before and after the treatment. The traditional group scored significantly higher in computational skill than the continuous progress group. There was no significant difference in arithmetic concepts or attitude.

Finally, individualized instruction fared very poorly in a study conducted in Volusia County, Florida (Sutton, 1967). Twenty eight seventh grade mathematics

teachers teaching thirty eight classes using learning packets and twenty seven classes by their usual teacher centered approach were involved in the study. In all, one thousand ninety one seventh graders comprised the classes. Reasoning and arithmetic fundamentals subtests of the California Achievement Battery were dependent variables. After the one year treatment, reasoning subtest means of the traditional group were significantly higher than the learning packet group with no significant difference in arithmetic fundamentals.

The findings in mathematics achievement are summarized in Table 3. Unlike the primary grades, the results in grades five to eight very definitely favor the non-individualized teaching approaches.

Table 3

Summary of Mathematics Achievement Results in Grades Five to Eight

Individualized Approach	Favored Individualized	Favored Control	NSD
IPI and PLAN	Project Skill, 1972	Fiedler, 1972 Brust, 1972 Ferney, 1970 Verheul, 1972 Thomas, 1972	Shumaker, 1973
Researcher or Teacher Prepared	Malcolm, 1973 Nix, 1970 (below average boys only)	Amendola, 1973 Whipple, 1972 Crangle, 1971 O'Neill, 1971 Schaefer, 1972 Sutton, 1967 Wheaton, 1972	Larsson, 1973 LaPlaca, 1974

On other criteria there is much more ambiguity, but it is very difficult to escape the conclusion that with students at this level individualized instruction has been a failure. Table 4 provides a summary of results on criteria other than mathematics achievement.

Table 4

Summary of Other Criteria in Grades Five to Eight

Variable	Favored Individualized	Favored Control	NSD
Attitude Toward Mathematics	Malcolm, 1973	Whipple, 1972	Project Skill, 1972 Shumaker, 1973 O'Neill, 1971 Larrson, 1973
Self-Esteem			Shaefer, 1972 Brust, 1972 Verheul, 1972
Study Habits			Shumaker, 1973 Crangle, 1971
Attitude Toward School	Thomas, 1972		Ferney, 1970 Amendola, 1973
Spontaneous & Adaptive Flexibility			Ferney, 1970
Self Perception of Competency			Ferney, 1970
Efficiency	LaPlaca, 1974.	Crangle, 1971 O'Neill, 1971	
Spatial Relations			Whipple, 1972

Educable Mentally Retarded Students

Only three studies were found which compared individualized instruction with other methods to teach educable mentally retarded (EMR) children. The results are mixed. Arrants (1973) used IPI with a group of twenty EMR students in the primary grades and conventional teaching methods with a second, comparable group of forty five students. Using mental age as a covariate he found a difference ($p < .01$) in arithmetic achievement favoring the IPI group but no significant difference in motor skills attained or in measures of acceptable behavior.

Wood (1973) also used IPI with a group of EMR students at the seventh, eighth and ninth grade level. No significant difference in mathematics achievement means was found between the IPI group and a traditional group after the treatment.

Tack (1972) reported no significant differences in mathematics achievement between two groups of second, third and fourth grade educationally deprived students. The experimental treatment group was instructed in a Westinghouse Learning Center using programmed instruction and methods of positive reinforcement while the control group was randomly selected from ten separate, heterogeneous, self-contained classroom with no special treatment. Suprisingly, with this pretest-posttest design the control group showed a significantly greater reading gain than the experimental group.

Interpretations

Individualized instruction of the type used in these studies is very expensive to adopt, and long run expenses, though they decrease over time, are still likely to exceed those in a traditional program (Edmunds, 1971; Frary, 1971; Gritzner, 1971). More work is expected of the teachers and most programs need, though

not always have, teacher aides or a computer to help with the management of the program (Edmunds, 1971; Frary, 1971; Lipson, 1974). A good deal of commitment of time and energies of school and/or outside personnel is needed to convince teachers, students, parents, and school boards that adoption is wise (Taylor and Fleming, 1973; Meade and Griffin, 1969; Johnson, 1972). Surely the burden of proof that there is some pay off for this added expense and effort lies with the advocates of this approach.

Thus, in interpreting the findings one should consider the traditional approach to be analogous to a defendant in a trial--that is, innocent until proven guilty. Findings of "no significant difference" do not mean one approach is just as good as the other. They mean "no evidence." The defendant is still innocent. The findings in kindergarten through grade four achievement which are summarized in Table 1 appear to be ambiguous at first glance. However, only five of the eighteen studies provide evidence against the traditional approach, and, in fact, five others are in the opposite direction. This is a very poor showing for an approach which demands so much extra effort and expense. Of course, Table 2 looks much better for the individualized approach especially on affective measures.

In grades five through eight the individualized approach has very definitely not been effective in mathematics as measured by any criteria used by these researchers. In fact, it is rare that a question in educational research has such a clear cut answer. The few studies supporting the individualized approaches are far outweighted by results favoring the traditional approaches even on affective measures. There is not enough evidence to draw any conclusions about individualization for EMR students.

Studies of the type reported here are always subject to criticism. For example, were the experimentors biased against one of the approaches? The answer is probably yes. With one or two exceptions the researchers set out to prove the effectiveness of their individualized approach. The reports are clearly written from that standpoint as evidenced by the time spent in explaining the individualized approaches and the tone of the interpretations of the results. If experimentor bias has affected the outcomes it has served to make them even less damaging to the individualized approach than they already are.

The Hawthorne Effect, or the novelty of being in a "new" program, can tend to temporarily inflate the outcomes in the experimental groups. Some of the findings favoring the individualized approach may be due to this effect. At any rate, if the Hawthorne Effect was a factor it also worked in favor of the individualized approach.

One might argue that the criterion tests were inappropriate. Theoretically, such an argument may have some substance. But from the practical standpoint, elementary school teachers are expected to leave the students with a firm grounding in arithmetic skills, reasoning, and applications. It will take more than a theoretical argument to convince the parents and tax payers that this should not be our major purpose in teaching arithmetic.

Based on the studies reviewed, students in grades five to eight seem to perform more poorly in individualized programs than those in the primary grades. One explanation for this is that the older children, unlike the younger ones, have already learned how to learn in a traditional classroom and must unlearn this before they can succeed under individualization. If that is true one would expect the

students in individualized programs to get better each year that the program is in operation. However, Taylor and Fleming (1972) found achievement differences in favor of IPI after one year of operation but in favor of the traditional group after the third year of IPI. In fact, only one of four other studies involving students in their second or third year of IPI reports achievement results in favor of IPI (Project Skill, 1972). Thomas (1972) reports greater achievement for the control group even though the IPI group was in their second year. Fiedler (1972) reports much greater achievement for the control group over the IPI group in a two year study(at the .001 and .002 probability levels).

Of course, it is impossible to know the quality of the teacher and researcher developed programs. Perhaps this type of individualization is a viable, even a superior, teaching approach but the practitioners simply failed to develop and execute it properly. Before jumping to that conclusion, however, it should be noted that IPI, after over ten years of development by experts under nearly ideal conditions, and PLAN with only a few less years fared no better than the teacher or researcher developed individualized programs.

Why were the individualized approaches not more successful? Some researchers speculated about the answer to this question, but studies of this type are not designed to provide data to help answer it. However, there is a fairly substantial body of recent research in which aspects of individualized instruction are studied. What types of students do best in this approach? What types of teachers? Are there sex differences? What content works best? What is the nature of student-teacher interaction in this approach? How does and should diagnosis and prescription take place? A review of this research is presently under preparation.

Do these findings carry into secondary and post secondary schools? Again recent research is very enlightening. A review of studies comparing individualized approaches with other approaches in secondary school and beyond is also being prepared.

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